

1	<b>Contents</b>	
2	3.7.2. Groundwater and Surface Water Quality .....	1
3	3.7.2.1. Introduction.....	1
4	3.7.2.2. Identified Issues and Cause-and-Effect Relationships of Concern .....	1
5	3.7.2.3. Analysis Methodology, Assumptions, and Uncertain and Unknown Information .....	1
6	3.7.2.4. Affected Environment.....	4
7	3.7.2.5. Environmental Consequences of Implementation of the Proposed Mine Plan and	
8	Alternatives .....	13
9	3.7.2.6. Cumulative Effects.....	14
10	3.7.2.7. Mitigation Effectiveness .....	14
11	Literature Cited .....	15

12	<b>Figures</b>	
13	Figure 3.7.2-1. General flow for water quality analysis.....	2
14	Figure 3.7.2-2. Groundwater analysis area .....	6
15	Figure 3.7.2-3. Overview of surface water quality analysis area .....	9

16	<b>Tables</b>	
17	Table 3.7.2-1. Number of groundwater samples available for analysis.....	7
18	Table 3.7.2-2. Rock units, alteration types, and number of samples submitted for geochemical	
19	evaluation .....	12

## 3.7.2 Groundwater and Surface Water Quality

### 3.7.2.1 Introduction

The proposed mine could potentially impact groundwater and surface water quality in several ways. The exposure of the mined rock to water and oxygen, both within the mine and then in stockpiles prior to processing, can create conditions under which acid rock drainage can occur, typically leading to elevated pH and high concentrations of dissolved metals. After processing, the tailings would be transported as a slurry, and with the exception of the filtered tailings in Alternative 4, the tailings slurry would be discharged into the tailings facility. Seepage from these tailings has the potential to enter underlying aquifers and impact groundwater quality. In addition, any contact of surface runoff with mined ore or processed tailings has the potential to result in surface water quality problems. Some aspects of the analysis are briefly summarized in this section. Additional details not included are captured in the project record (Newell and Garrett 2018).

### 3.7.2.2 Identified Issues and Cause-and-Effect Relationships of Concern

Please see the November 2017 report titled “Resolution Copper Project and Land Exchange Environmental Impact Statement: Final Summary of Issues Identified Through Scoping” (Issues Report) for a complete listing and discussion of the analysis factors for alternative comparison related to groundwater and surface water quality and the Resolution Copper Project and Land Exchange (SWCA Environmental Consultants 2017).

#### **Primary Factors to Analyze Changes to Groundwater and Surface Water Quality (Issue #2C, #6B, and #6D)**

- Estimated changes in groundwater quality in area of block cave
- Estimated changes in groundwater quality due to seepage from tailings
- Ability to meet Arizona aquifer and surface water quality standards
- Potential for spills

### 3.7.2.3 Analysis Methodology, Assumptions, and Uncertain and Unknown Information

Because the environments for each tailings facility and the block-cave area are hydrologically and geologically different, different analysis tools have been used for each situation. In general, however, a similar process was followed for each (figure 3.7.2-1).

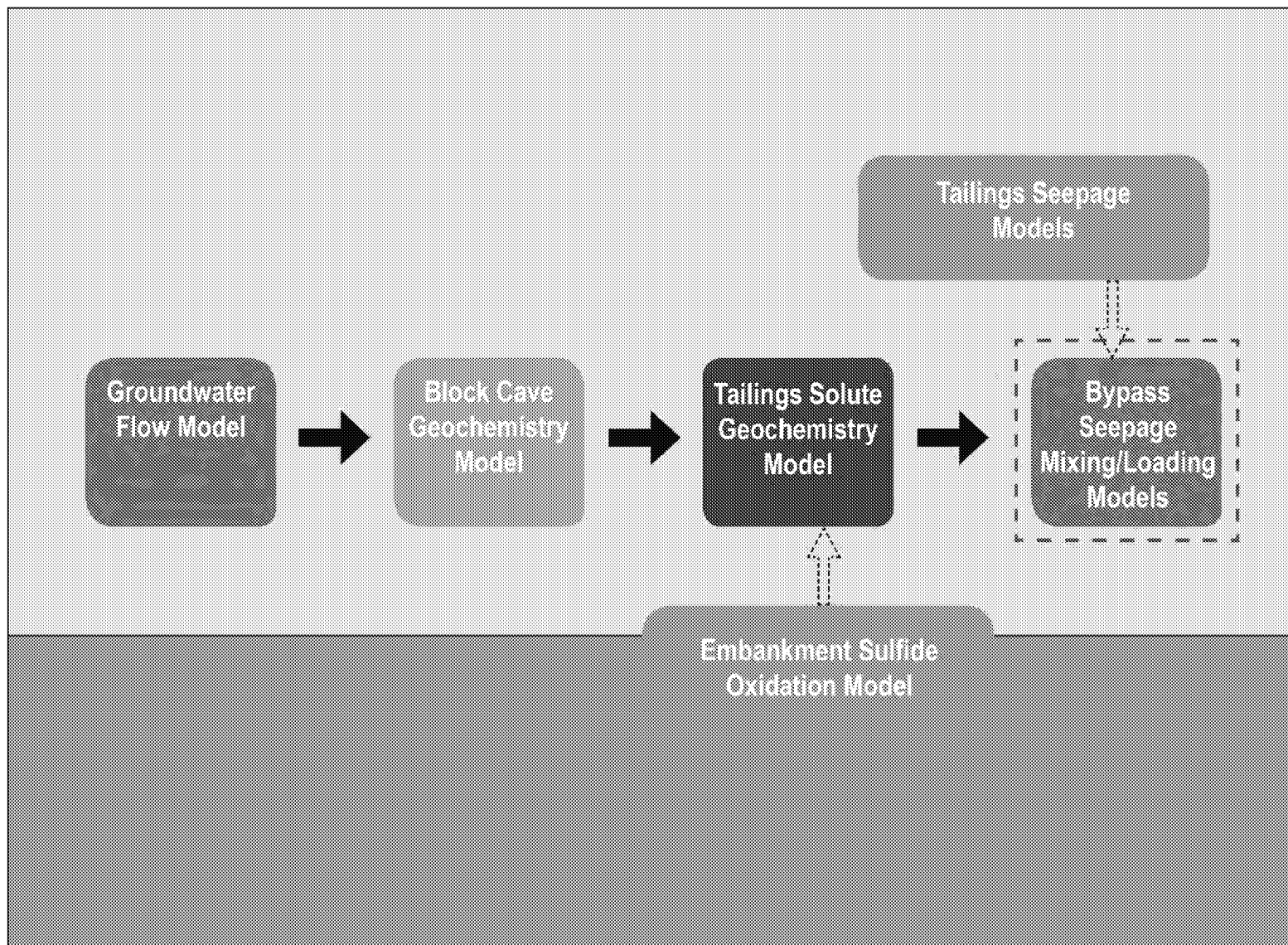


Figure 3.7.2-1. General flow for water quality analysis

## **Block-Cave Zone**

The regional groundwater flow model discussed in the “Groundwater Quantity and Groundwater-Dependent Ecosystems” section provided information on the inflows and outflows from the block-cave zone. This information fed into a block-cave geochemistry model that predicts the changes in the block-cave zone during operation of the mine (Eary 2018f).

## **Tailings Solute Geochemistry Model**

The water balance for the mine is complex, with multiple sources and recycling loops, and forms the fundamental basis for predicting the solute water quality in the tailings facility. The water balance differs for each tailings alternative (Golder Associates Inc. 2018; Kloth Crippen Berger Ltd. 2018a, 2018b, 2018c, 2018d; WestLand Resources Inc. 2018). Chemical loading inputs are applied to each water source, and the resulting water quality is calculated with a mixing model (PHREEQC) for the entire operational life of the mine, at six specific points in the process (Eary 2018a, 2018b, 2018c, 2018d, 2018e, 2018g):

- the mixture of water entering the West Plant Site;
- the pyrite pond; the scavenger pond;
- the water within the pore space of the tailings embankment;
- the seepage collection ponds; and
- the seepage lost to underlying aquifers.

## **Embankment Sulfide Oxidation Model**

During operations, the tailings most likely to cause water quality problems—the pyrite tailings—would be kept in a subaqueous state with an overlying water cap to prevent oxygen from reaching and interacting with the tailings. During closure, the water cap would gradually be replaced with a thick cover of scavenger tailings and a reclamation cover. The fine-grained tailings on the interior of the facility are expected to exhibit a low vertical permeability and a high moisture content, and oxygen is not expected to penetrate the tailings at rates sufficient to affect seepage chemistry for hundreds of years (Wickham 2018).

However, the embankments of the tailings facility are constructed of well-drained cyclone sands. The same is true of the entirety of the dry stack facility (Alternative 4). Oxygen would enter these areas and react with minerals over time. Analysts used a sulfide oxidation model to predict changes in water quality from the embankment areas for the 41 years of operation and an additional 204-year postclosure period (Wickham 2018).

## **Tailings Seepage Mixing Models**

The water quality of the tailings solute, the changes in water quality from the embankment, and the predicted amounts of seepage from the facility, are input into mixing models that predict the changes in seepage water quality over time and the changes in aquifer water quality downstream from each tailings facility. The modeling for each tailings facility uses different tools to accomplish this task:

- **Near West (Alternatives 2 and 3).** At the Near West tailings location, seepage from the facility is estimated using a three-dimensional steady-state model (Groenendyk and Bayley 2018). The downstream mixing model then estimates groundwater quality in five different cells, which include Queen Creek to Whitlow Ranch Dam, Robles Canyon, and Potts Canyon for the 41 years of operation and an additional 204 years postclosure (Gregory and Bayley 2018d).

- 1 • **Silver King (Alternative 4).** Even though this alternative is a dry stack, some seepage is still  
2 expected to occur with Alternative 4, though a very small amount, compared with the slurry  
3 alternatives. The downstream mixing model estimates groundwater quality in nine cells,  
4 which include Queen Creek to Whitlow Ranch Dam, Potts Canyon, Silver King Wash, and  
5 Happy Camp Wash East and West (Gregory and Bayley 2018a).
- 6 • **Peg Leg (Alternative 5).** The Peg Leg location is fundamentally different from the other  
7 locations in that it overlies a large alluvial aquifer, resulting in relatively large seepage rates,  
8 compared with other alternatives. The downstream mixing model estimates groundwater  
9 quality in five cells along Donnelly Wash to the Gila River (Gregory and Bayley 2018b).
- 10 • **Skunk Camp (Alternative 6).** The Skunk Camp location is similar to Near West, but the  
11 alluvial aquifer downstream associated with Dripping Spring Wash is more substantial than  
12 those at Near West. The downstream mixing model estimates groundwater quality in five  
13 cells along Dripping Spring Wash to the Gila River (Gregory and Bayley 2018c).

#### 14 ***Geochemistry Workgroup***

15 Similar to geology and subsidence and groundwater modeling, a multidisciplinary workgroup was formed  
16 to evaluate the techniques, assumptions, and processes used by Resolution Copper to assess water quality.  
17 The workgroup includes specialists from the NEPA team in geochemistry, hydrology, and tailings and  
18 mine processes. The workgroup held the initial meeting in November 2016; the workgroup continues to  
19 meet to complete the evaluation of technical work.

#### 20 ***Constituents of Concern***

21 Much of the analysis we present in this section focuses on selected “constituents of concern.” These are  
22 constituents that are typically known to be issues for similar sites, or that site-specific testing has  
23 indicated may be a problem. The background references contain information for all samples collected and  
24 all constituents. Constituents of concern include the following:

- 25 • Total dissolved solids
- 26 • Sulfate
- 27 • Common metals: copper, selenium

28 [Note to reviewers: This list to be expanded as environmental consequences section is completed]

#### 29 **3.7.2.4 Affected Environment**

#### 30 ***Relevant Laws, Regulations, Policies, and Plans***

31 For the most part, impacts to groundwater and surface water quality fall under State of Arizona  
32 regulations.

## Primary Legal Authorities Relevant to the Groundwater and Surface Water Quality Analysis

- State of Arizona Aquifer Water Quality Standards and the Aquifer Protection Permit Program
- State of Arizona Surface Water Quality Standards and the Arizona Pollutant Discharge Elimination System Program (delegated primacy for Clean Water Act Section 402)

### **Existing Conditions and Ongoing Trends**

The general hydrologic framework of the project area is described in the “Groundwater Quantity and Groundwater-Dependent Ecosystems” section. With respect to predictions of impacts to groundwater and surface water quality, three aspects of the affected environment are pertinent:

- Existing groundwater quality for various aquifers, including what types and quantity of data have been collected to date; the general geochemistry of the groundwater for major constituents; the occurrence and concentrations of “constituents of concern,” compared with water quality standards; the age of the groundwater; and existing trends in groundwater quality.
- Existing surface water quality for various streams, including what types and quantity of data have been collected to date; the general geochemistry of surface waters for major constituents; and the occurrence and concentrations of constituents of concern, compared with water quality standards.
- Characterization of mine rock, including the types and quantity of data for different geological units that have been collected to date, and the static and kinetic laboratory testing undertaken to describe the likely changes in water quality when exposed to mine rock.

### **EXISTING GROUNDWATER QUALITY**

**What kinds of groundwater are present?** As more fully described in Section 3.7.1, Groundwater Quantity and Groundwater-Dependent Ecosystems, in the project area groundwater exists in three different operational zones, or aquifers. These aquifers comprise shallow groundwater occurring in shallow alluvial materials, perched zones, or shallow fractures, the Apache Leap Tuff aquifer, and the deeper aquifer (units generally below the Whitetail Conglomerate, and extending into the Superior Basin) as seen in figure 3.7.2-2. These zones are identified as separate owing to the different ages of the water within them and because they do not appear to be hydraulically connected. In the process area and at the Peg Leg location, there is only one identified aquifer for each location.

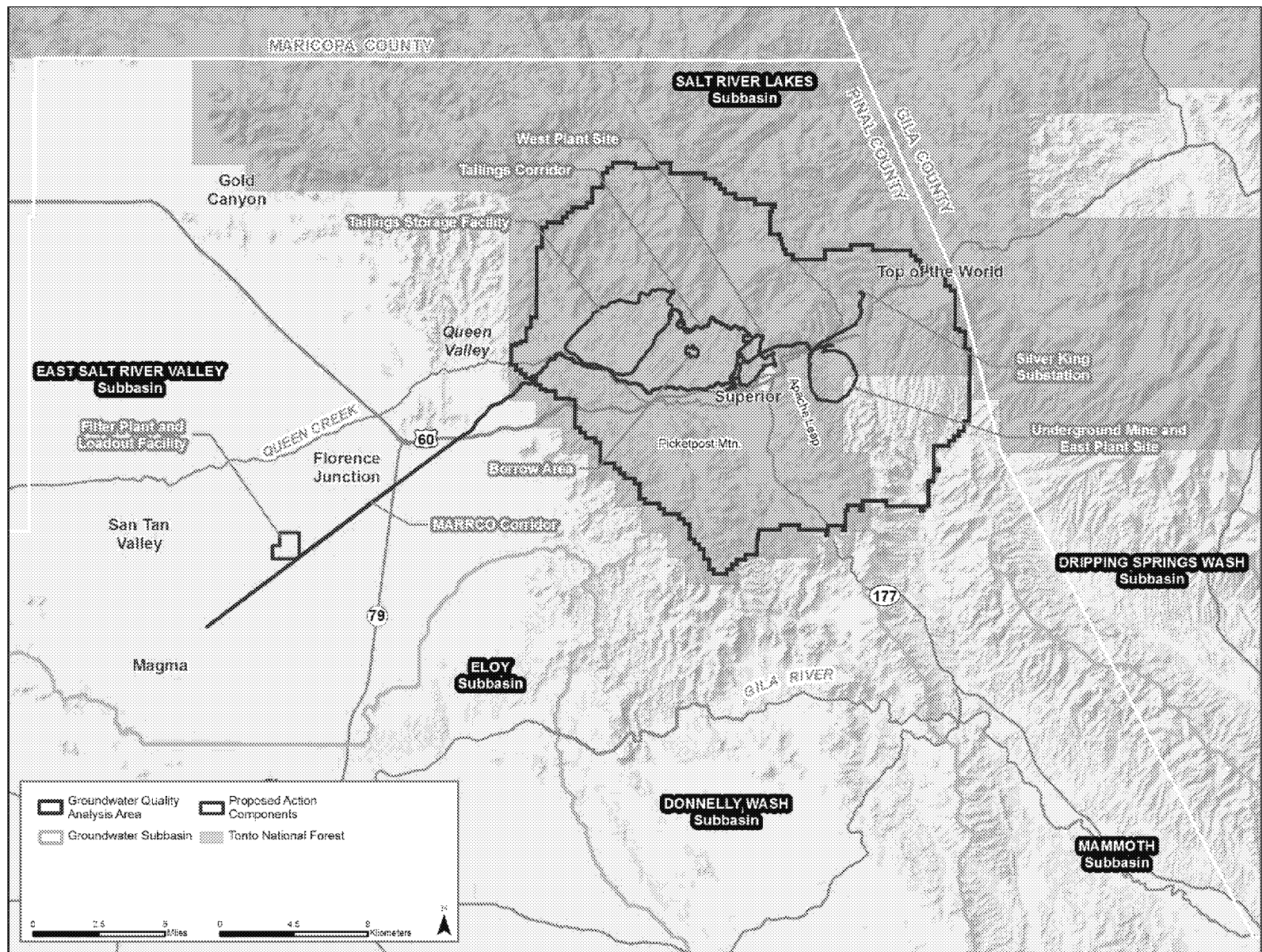


Figure 3.7.2-2. Groundwater analysis area

**How much data has been collected over what period of time?** Groundwater quality data have been collected since monitor well drilling and development was initiated in 2004, and collection continues to the present. Each monitoring well that is constructed is sampled for chemical analysis. In addition to analyzing each well as constructed, a series of samples was collected from all wells in the project area for six consecutive quarters beginning in early 2008 and continuing into 2009. Additional data have been collected more recently since 2017. Overall, 31 wells in the project area have been sampled since 2004, and through 2015, a total of 150 samples has been collected to characterize groundwater in the project area. Near the West Plant Site, 48 wells have been developed and sampled, from 2015–2017, yielding 102 samples of groundwater (including duplicate samples). This sampling has largely been the result of ongoing voluntary cleanup activities. Very few groundwater samples have been collected at or near the Silver King, Peg Leg, or Skunk Camp locations.

**What kinds of data have been collected?** All samples were analyzed for a wide range of chemical constituents. Some water quality measurements were made on water samples in the field at the point of collection (e.g., pH, temperature) and others were submitted to an Arizona-certified analytical lab for additional analyses. Some of the constituents are directly related to water quality, including those that have regulatory standards in the state of Arizona. Other constituents are generally unrelated to basic water quality and more useful for understanding groundwater dynamics and the potential for interaction with local surface water resources (Garrett 2018), such as isotopes. We analyzed samples primarily for inorganic constituents, including metals, but we did not typically analyze for organic constituents, such as petroleum hydrocarbons, pesticides, or solvents. The number, date range, and types of samples collected are shown in table 3.7.2-1.

**Table 3.7.2-1. Number of groundwater samples available for analysis**

Type of Analysis	Shallow Groundwater Samples	Apache Leap Tuff Samples	Deep Groundwater Samples
General chemistry	25 (June 1986–Nov 2015)	104 (March 2004–Dec 2015)	19 (Nov 2008–Feb 2015)
Metals	25 (June 1986–Nov 2015)	105 (March 2004–Dec 2015)	19 (Nov 2008–Feb 2015)
Isotopes	24 (June 1986–May 2012)	90 (March 2004–Dec 2015)	19 (Nov 2008–Feb 2015)
Radionuclides	12 (June 2007–Dec 2008)	63 (June 2007–Dec 2015)	19 (Nov 2008–Feb 2015)

**What is the chemical quality of groundwater (type, quality, and occurrence of constituents of concern)?** There are differences in water quality among the three principal groundwater sources (shallow, deep, and Apache Leap Tuff) in the project area (Montgomery and Associates Inc. 2012, 2016). Shallow and Apache Leap Tuff sources are of good quality with few measured exceedances of Arizona or Federal water quality standards, while deep groundwater quality can be problematic and variable.

The shallow groundwater system’s water quality is good and can be described as a calcium/magnesium bicarbonate type with varying amounts of sulfate. The total dissolved solids content is generally low, and has a median of 290 milligrams per liter (mg/L). Water samples from the shallow groundwater system did not exceed any Arizona Numeric Aquifer Water Quality Standards (AWQS) or EPA National Primary Drinking Water Regulations. Some EPA National Secondary Drinking Water Regulations (NSDWR) were exceeded, primarily for iron and manganese, with several exceedances for sulfate and total dissolved solids.

The Apache Leap Tuff aquifer has been sampled much more than either the shallow or deep systems. Overall the Apache Leap Tuff is a calcium-magnesium-bicarbonate water type. Median total dissolved



solids is 217 mg/L. AWQS reference values were met in all but a couple of samples (antimony, thallium, and beryllium) and all samples were below National Primary Drinking Water Regulations standards. As with the shallow and deep groundwater, NSDWR standards for iron and manganese were routinely exceeded.

The overall water quality of the deep aquifer is more variable than the shallow and Apache Leap Tuff systems, often with greater total dissolved solids that exceeds the NSDWR reference criterion; the median total dissolved solids is 410 mg/L. Only one sample in 2011 exceeded AWQS values. NSDWR reference values were exceeded primarily for iron and manganese, with some exceedances for sulfate and total dissolved solids. Samples with elevated sulfate, total dissolved solids, iron, and manganese appear to be within the proposed mineralized ore zone (Montgomery and Associates Inc. 2012).

Groundwater is also extracted from Shaft No. 9 as part of the ongoing dewatering. Groundwater associated with discharge from Shaft No. 9 is very poor water quality. It has very high sulfate concentrations and, by extension, elevated total dissolved solids. Numerous exceedances of AWQS, National Primary Drinking Water Regulations, and NSDWR have been documented. This sampling location should not, however, be considered representative of the deep aquifer system as it appears to be affected by mine activity. The impacts at this location appear to be influenced by sulfide mineral oxidation, although the solution is routinely near neutral pH.

**What is the age of the groundwater?** Chemical characteristics of groundwater (isotopes) that may be used to assess the age do not have explicit regulatory standards. However, carbon-14 ( $^{14}\text{C}$ ) and tritium have both been measured in shallow, deep, and Apache Leap Tuff aquifers to constrain age and provide understanding of water movement. These isotopic measurements indicate that shallow groundwater is typically estimated to be less than 700 years old, whereas deep and Apache Leap Tuff water is 3,000–5,000 and 6,000–15,000 years old, respectively.

**Are there ongoing trends in groundwater quality?** Over time (as much as 6 years), water quality, in terms of major chemical constituents (e.g., calcium, magnesium, bicarbonate, sulfate) has remained generally stable in the shallow and Apache Leap Tuff aquifer systems. The shallow system has displayed the greatest amount of variation and has the shortest period of time over which samples have been reported, but has been largely confined to variations in sulfate concentration. Although data for deep groundwater show significant variation with location, available data indicate there is little seasonal variability.

#### EXISTING SURFACE WATER QUALITY

Surface water occurs broadly across the entire project area. The settings in which surface water occurs span a wide range, from small to large drainage areas and channels and with highly variable flow rates, see figure 3.7.2-3. Being locations at which groundwater emerges, springs can be viewed as representative of groundwater, but are included here with surface water to emphasize their important contribution to surface flows and their significance as a resource to wildlife.

The kinds of surface water present are described in detail in both the “Groundwater Quantity and Groundwater-Dependent Ecosystems” and “Surface Water Quantity” sections in this chapter.

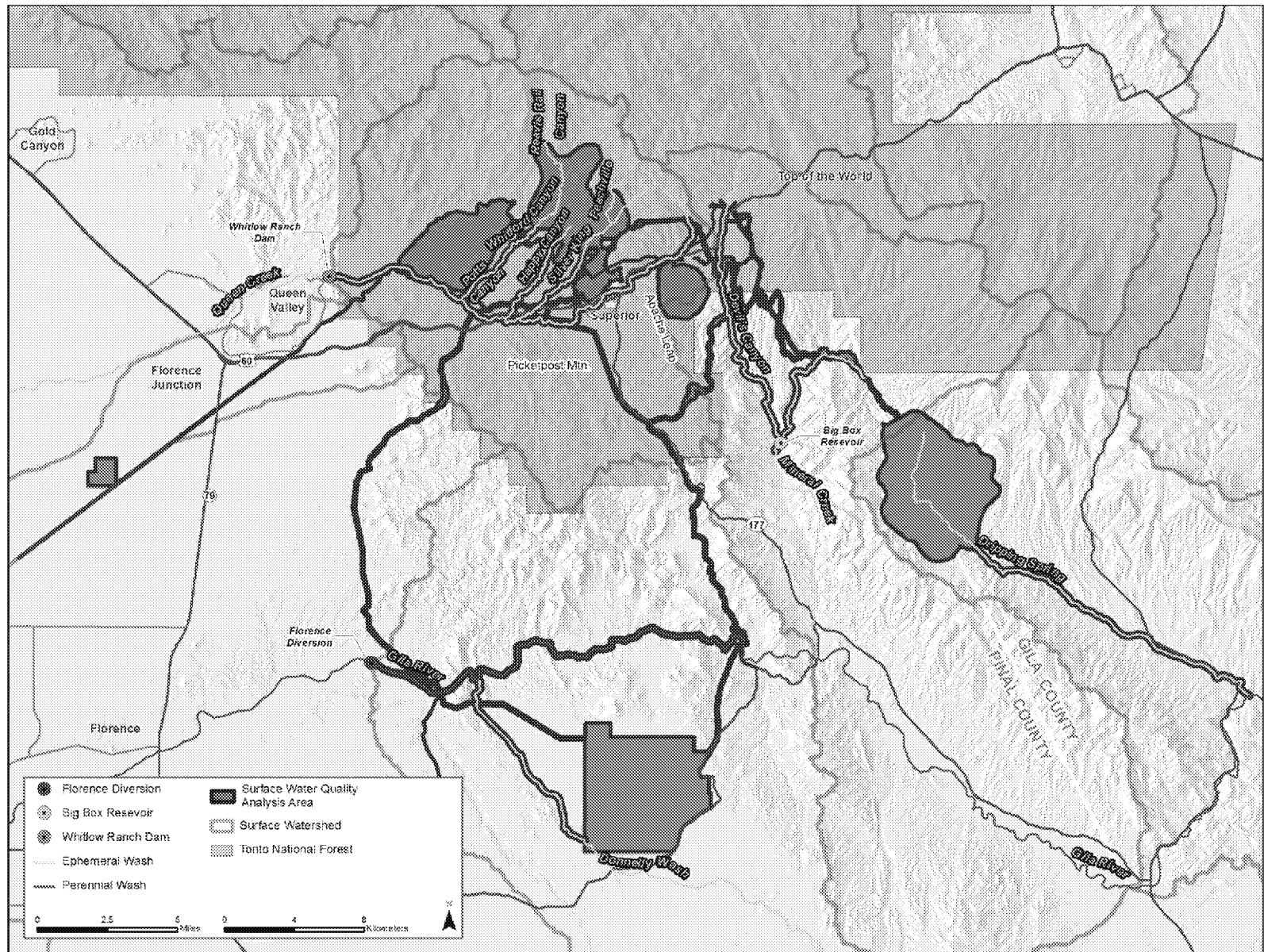


Figure 3.7.2-3. Overview of surface water quality analysis area

**How much data has been collected over what period of time?** The surface water baseline monitoring program for the project area was initiated in 2003 and has continued through 2015, with a 2-year hiatus in 2006 and 2007. Although surface water data have been collected from 2003 through 2015, the number of samples collected varies from location to location and no locations have been sampled every year. Water quality data are available for a total of 47 locations. Through 2015, 505 samples of surface water have been collected and chemically analyzed for 37 water quality parameters.

Most surface water monitoring has been conducted in the Devil's Canyon watershed (main canyon and two tributaries). Queen Creek, along the northern margin of Oak Flat prior to entering the Superior area, has also been extensively characterized (Montgomery and Associates Inc. 2013, 2017).

**What kinds of data have been collected?** As with groundwater, all samples were analyzed for a wide range of chemical constituents. Some water quality measurements were made on water samples in the field at the point of collection (e.g., pH, temperature) and others were submitted to an Arizona certified analytical lab for additional analyses. Some of the constituents are directly related to water quality, including constituents that have regulatory standards in the state of Arizona. Other constituents are generally unrelated to basic water quality and more useful for understanding the systematics of groundwater dynamics and its potential interaction with local surface water resources. These constituents include a range of element isotopes, the proportions of which are routinely used to understand hydrologic systems. They are primarily naturally occurring and are unrelated to any human-based contamination. Samples were not analyzed for any organic constituents, such as petroleum hydrocarbons, pesticides, or solvents.

**What is the chemical quality of surface water (type, quality, and occurrence of constituents of concern)?** In general, surface water associated with the proposed project is a calcium-sodium-bicarbonate type, with a neutral to alkaline pH. The major element composition of surface water does not vary widely across the project site and does not show any identifiable long-term trends, either increasing or decreasing. However, in Devil's Canyon and Queen Creek, statistically significant short-term seasonal trends have been identified for copper (Devil's Canyon) and sulfate (Devil's Canyon and Queen Creek). These seasonal trends appear to be linked with increased precipitation, with higher concentrations observed during periods of increased runoff in the winter rainy season and summer monsoons. The increases are likely due to washing of evaporative salts that may form during drier times of the year. During drier periods, surface water appears to be supported more by groundwater discharge and is more chemically stable. No significant seasonal variability in sulfate or bicarbonate was observed for springs or surface waters in the Queen Creek or Mineral Creek watersheds. No consistent temporal trends were identified for chloride, sodium, potassium, calcium, or magnesium anywhere in the project area. Appendix J, table J-2 presents a summary of water quality for defined reaches of the principal drainages, for filtered water samples. Appendix J, table J-3 presents the same types of data for unfiltered samples.

For the three principal drainages associated with the project—Queen Creek, Mineral Creek, and Devil's Canyon—water quality is generally good, although all three have exceeded applicable Arizona surface water quality standards at different times for several different constituents (Montgomery and Associates Inc. 2013, 2017). Most notably, Queen Creek, from the headwaters of Potts Canyon, is listed by the ADEQ as impaired for copper. Overall, dissolved copper concentrations were significantly higher at sites in the Queen Creek watershed than in the Devil's Canyon and Mineral Creek watersheds; dissolved copper concentrations in the Devil's Canyon watershed generally decreased with distance downstream, and were significantly higher than in the Mineral Creek watershed.

For the defined reaches of the major drainages, samples that exceed Arizona surface water quality standards (Arizona Department of Environmental Quality 2009) exist, and are primarily associated with aquatic and wildlife standards, both acute and chronic. Thallium appears to be more problematic than

most constituents, with concentrations exceeding standards for drinking water and fish consumption. Appendix J, table J-4 summarizes the number of samples that were identified as exceeding standards. For appendix J, table J-4, grayed areas indicate that no standard exists, for either that chemical constituent or for the specific exposure pathway (Arizona Department of Environmental Quality 2009). Cited standards for constituents that are not based on the hardness of the water are shown at the head of each constituent section. Where no standard is listed, the applicable standard is based upon the hardness of the water (the amount of calcium and magnesium in the water) and is variable.

## MINE ROCK ANALYSIS

Rock within the proposed subsurface zone of mining is highly mineralized. However, not all the rock that is mineralized is ore grade and identified for proposed recovery. Much mineralized rock will remain in place during, and after mining. This rock contains sulfide minerals (e.g., pyrite, iron disulfide) and other metal-containing material. During mining, and after mining for some time, exposure of these minerals to oxygen will lead to their chemical weathering. This weathering may contribute acidity and metals to contact water and diminish its overall quality. The mine rock has been sampled and analyzed to assess the extent to which it might affect water that accumulates and is removed during mining, as well as the potential effects on groundwater that floods the mine void after mining is completed.

**What kinds of data have been collected?** Mine rock has been evaluated using a range of established, standard (best practices) methods for the mining industry (International Network for Acid Prevention 2018) as well as those that are regulatorily mandated procedures (Arizona Department of Environmental Quality 2004). These methods assess

- the potential for rock to generate acidic drainage,
- the rate at which such acid generation may occur, and
- what constituents of concern might be released and their associated concentrations.

Specific methods include

- whole rock chemical composition (concentration of wide range of elements),
- acid-base accounting (Sobek et al. 1978),
- net acid generation test (Stewart et al. 2006),
- synthetic precipitation leaching procedure (U.S. Environmental Protection Agency 1994),
- humidity cell testing (American Society for Testing and Materials 1996), and
- saturated column testing (a project-specific test to leach the residual humidity cell testing procedure material).

The first four procedures (whole rock chemical composition, acid-base accounting, net acid generation test, and synthetic precipitation leaching procedure) are Tier 1 procedures required in the Arizona Best Available Demonstrated Control Technology (BADCT) guidance (Arizona Department of Environmental Quality 2004). The last two are called for in the Tier 2 test level requirements.

Beyond these chemical testing methods that directly assess potential impacts on the quality of contacting water, mine rock has been evaluated using mineralogical techniques such as

- petrography (microscopic evaluation of mineral grain sizes and contact boundaries),
- x-ray diffraction (identifies actual minerals present and their abundance), and

- scanning electron microscopy (evaluation of mineral textures).

**How much data have been collected?** Various rock units make up mine rock. Over geological time, temperatures in the earth alter the original rock type, which modifies its original mineralogy to some degree. Overall, the combination of rock units and types forms the range of materials that occurs in the mineralized zone.

MWH Americas (2013) reports the rock units and alteration types that have been evaluated, and the number of samples for each. This information is summarized in table 3.7.2-2. Overall, 226 samples were submitted for analysis of Tier 1 procedures, with 13 duplicates for a total of 239 samples. Following completion of Tier 1 testing, 15 samples were identified and submitted for Tier 2 evaluation.

**Table 3.7.2-2. Rock units, alteration types, and number of samples submitted for geochemical evaluation**

Code	Rock Unit	Count
Tal	Tertiary Apache Leap Tuff (Ignimbrite)	7
Tw	Tertiary Whitetail Conglomerate	11
Kvs	Cretaceous volcanics and sediments (undifferentiated)	101
Kqs	Cretaceous quartz-rich sediments	1
QEP	Quartz eye porphyry; rhyodacite porphyry	37
FP/LP	Felsic porphyry; latite porphyry	3
Dm	Devonian Martin limestone (skarn)	21
Andesite	Andesite	1
Diabase	Diabase	22
Qzite	Quartzite	17
Breccia/Hbx	Heterolithic breccia	3
Fault	Fault	2
	<b>Total</b>	<b>226</b>
Alteration Type		
Code	Rock Unit	Count
AA	Advanced argillic	19
ARG	Argillic	1
HFLRET	Retrograde hornfels	5
PHY	Phyllic	111
POT	Potassic	31
PRO	Propylitic	16
SA	Supergene argillic	7
SIL	Siliceous	1
SKN/SKRET	Skarn/Retrograde skarn	16
UNALT	Unaltered	18
ZEO	Zeolite	1
	<b>Total</b>	<b>226</b>

### 3.7.2.5 Environmental Consequences of Implementation of the Proposed Mine Plan and Alternatives

#### ***Direct and Indirect Effects of Each Alternative***

[Note to reviewers: All Environmental Consequences is pending completion of the Geochemistry Workgroup review of Resolution Copper's analysis]

#### POTENTIAL FOR CRATER LAKE DEVELOPMENT

Three simultaneous events will take place that suggest the potential for the creation of a surface lake on Oak Flat after closure of the mine:

- The subsidence crater will develop. The base case model run indicates the crater would be about 800 feet deep. Most of the sensitivity runs of the subsidence model are similar, although one sensitivity model run reached about 1,100 feet deep (Itasca Consulting Group 2018).
- Groundwater levels will rebound as the aquifer equilibrates after dewatering is curtailed after closure of the mine.
- Block-caving will have created a hydraulic connection essentially from the surface to the deep aquifer and eliminated any aquitard layers like the Whitetail Conglomerate.

The Groundwater Modeling Workgroup explored the potential for a crater lake to form. Ultimately the group determined that the presence of a crater lake was speculative and not reasonably foreseeable, and as such it would therefore be inappropriate to analyze in the EIS. Further, the uncertainties are such that it would not be possible to adequately analyze a crater lake, even if it were appropriate to do so. The Groundwater Modeling Workgroup determined this based on the following rationale:

- For a crater lake to form, groundwater levels would have to rebound to an elevation greater than the bottom of the subsidence crater. Resolution Copper modeled this as taking about 980 years, or possibly as early as 500 years based on some of the sensitivity analyses. The Groundwater Modeling Workgroup identified 200 years as being the limit of reliability for predictions obtained from the groundwater flow model.
- The presence of a crater lake depends heavily on the absolute elevation of the bottom of the crater. While there is little doubt that a subsidence crater would develop, modeling the magnitude of subsidence carries substantial uncertainty, and the exact elevation of the bottom of the subsidence relies on accurate predictions of subsidence magnitude.
- The presence of a crater lake depends equally heavily on the absolute elevation of the water table as it rebounds. While there is also little doubt that groundwater levels would rebound after cessation of dewatering, the absolute elevation of model results is one of the most uncertain aspects of modeled predictions. In fact, it is for this reason that drawdown, not absolute elevations, was used in prediction of impacts to GDEs. Drawdown relies on a comparison of starting water levels with future water levels; if there are errors in calibration at a specific location, using drawdown effectively negates these errors. Absolute elevation, on the other hand, would incorporate any calibration errors. The model as a whole is well calibrated, but individual spot locations could show calibration errors of dozens of feet, in places over 100 feet.

While the fundamental processes needed to create a crater lake are reasonably foreseeable—rebounding water levels, subsiding ground surface, fracturing of aquitards—the long time frames involved, compounded by the uncertainty of both the subsidence and groundwater models, provides no reasonable

basis to predict that these processes will come together in a way that will actually create a lake within the subsidence crater.

Similarly, if a lake developed, these combined uncertainties make it impossible to predict the details that would be necessary to conduct even a rudimentary analysis of effects. For instance, the depth of the lake cannot be known with any accuracy. However, that single parameter would affect both the amount of inflow of native groundwater and the amount of evaporation that would occur from the lake surface, and it is the interplay of these two parameters that largely determines how constituents would concentrate in the lake and whether the ultimate water quality would be hazardous to wildlife.

#### 3.7.2.6 Cumulative Effects

[Note to reviewers: Please review cumulative effects analysis in separate memorandum.]

#### 3.7.2.7 Mitigation Effectiveness

The Forest Service is in the process of developing a robust mitigation plan to avoid, minimize, rectify, reduce, or compensate for resource impacts that have been identified during the process of preparing this EIS. Appendix F contains descriptions of mitigation concepts being considered and known to be effective, as of publication of the DEIS. Appendix F also contains descriptions of monitoring that would be needed to identify potential impacts and mitigation effectiveness. As noted in chapter 2 (section 2.3), the full suite of mitigation would be contained in the FEIS, required by the ROD, and ultimately included in the final GPO approved by the Forest Service. Public comment on the EIS, and in particular appendix F, will inform the final suite of mitigations.

This section contains an assessment of the effectiveness of design features from the GPO and mitigation and monitoring measures found in appendix F that are applicable to groundwater and surface water quality.

### **DESIGN FEATURES**

#### **REQUIRED BY FOREST SERVICE OR BLM**

#### **REQUIRED BY OTHER AGENCY/PERMIT**

[Caution: no prescriptive detail, just reference]

#### **VOLUNTARY BY RESOLUTION COPPER**

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